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WASTE PACKAGE TRANSPORT AND EMPLACEMENT VEHICLE GAP ANALYSIS STUDY

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ACRONYMS

BSC	Bechtel SAIC Company, LLC
BOD	Basis of Design (Document)
DOE	U. S. Department of Energy
ITS	important to safety
NSDB	Nuclear Safety Design Bases
P&ID	Process and Instrumentation Diagram
SSCs	structures, systems, and components
TAD	transportation, aging, and disposal
TEV	transport and emplacement vehicle
WP	waste package

1. PURPOSE AND SCOPE

To date, the project has established performance requirements for important to safety (ITS) structures, systems, and components (SSCs) based on the identification and categorization of event sequences that may result in a radiological release. These nuclear safety design bases (NSDB) requirements are defined within the *Basis of Design for the TAD Canister-Based Repository Design Concept* (BOD) (Reference 9.1.1). Assurance that these SSCs will perform as required is sought through the use of consensus codes and standards.

This gap analysis study is based on the design development completed for license application only. Accordingly, the identification of ITS SSCs beyond those defined within the BOD is based on designs that may be subject to further development during detail design. Furthermore, several design alternatives may still be under consideration to satisfy certain safety functions, and that final selection will not be determined until further design development has occurred.

Demonstration of assurance that a component of an ITS SSC will perform as required will be achieved by following an established code or standard that prescribes how the component is to be designed, fabricated, and tested. However, due to the specialized nature of the waste package transport and emplacement vehicle (TEV), consensus codes and standards may not be fully applicable. In order to satisfy project performance requirements, studies and evaluations have been performed to identify specific design areas which perform ITS functions, identify codes and standards used to ensure these functions are performed as required, and determine where performance acceptance cannot readily be achieved through the use of consensus codes and standards. Since TEV components are based on existing technology, design studies performed to evaluate applicable codes and standards have found that ITS functions and requirements can be met using codes, standards and supplemental requirements developed specifically for industrial and nuclear crane applications.

This gap analysis will evaluate each code and standard identified within the *Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2) to ensure each NSDB requirement is fully satisfied. When a requirement is not fully satisfied, a gap is highlighted. This gap analysis study will identify requirements to supplement or augment the code or standard to meet NSDB requirements. Further, the gap analysis will identify nonstandard areas of the design that will be subject to a design development plan. Non-standard components and nonstandard design configurations are defined as areas of the design that do not follow standard industry practices or codes and standards; assurance that these SSCs will perform as required cannot be readily sought through use of consensus standards.

The information contained in this document has been developed by Subsurface Engineering / Mechanical in its work regarding codes and standards gaps for Emplacement and Retrieval. Yucca Mountain Project personnel from Subsurface Engineering / Mechanical should be consulted before use of this gap analysis study for purposes other than those stated herein or used by individuals other than authorized personnel in Subsurface Engineering / Mechanical.

1.1 QUALITY ASSURANCE

This informal study was prepared in accordance with EG-PRO-3DP-G04B-00016, *Engineering Studies* (Reference 9.1.4). The results presented are only to be used as the basis for the selection of applicable codes and standards and are not to be used directly to generate quality-affecting products. Therefore, this gap analysis study is not subject to requirements of the *Quality Management Directive* (Reference 9.1.3) document.

2. METHODOLOGY

The NSDB requirements applicable to the transport and emplacement vehicle (TEV) were extracted from the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Reference 9.1.1) and inserted into the gap analysis table found in the Section 10. Each component part of the TEV was assessed against each of the NSDB requirements. SSCs credited with performing safety functions were identified in the *Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2) and are listed in the gap analysis table. The gap analysis table is comprised of three sections:

- Code and standard applicability
- Supplemental requirements
- Design development requirements

If a code or standard is identified and adequately satisfies the NSDB requirement, it is entered into the ‘code and standard applicability’ section of the table. The rationale for code or standard selection is found in Section 4.4.

Where a code or standard does not sufficiently address an NSDB requirement, a supplemental requirement may be specified. A supplemental requirement is typically an interpretation or amplification of a code or standard and often results in additional requirements for analysis, modeling, inspection, or testing. For example, the standard may permit more than one method of performing an analysis, or may specify the minimum acceptable design margins or testing requirements. A supplemental requirement may be used to dictate the analytical methodology, specify greater design margins, or require additional testing. These additions were entered in the ‘supplemental requirements’ section of the table.

If the application of a code or standard and associated supplemental requirements do not adequately address the NSDB requirement, a need for design development exists. These “gaps” result in identification of design development requirements to ensure that the design will satisfy the NSDB requirement. These requirements are identified in the ‘design development requirements’ section of the table and will be further detailed in the design development plan.

3. TRANSPORT AND EMPLACEMENT VEHICLE FUNCTIONAL DESCRIPTION

The function of the WP transport and emplacement vehicle (TEV) is to transfer a WP and its associated emplacement pallet from the WP loadout room within a surface facility, through the

North Portal, down the Access Main, and onto the final emplacement position within the emplacement drift. The TEV can be used for waste package and pallet removal / relocation / retrieval where the process is a reversal of the emplacement procedure.

The TEV is designed to be radiologically shielded, electrically powered, self-propelled, rail-based, and remotely controlled. It will run on standard crane rails and is capable of operating within the surface facilities, North Portal, Access Main, and the emplacement drifts bounding envelope and environment.

To perform its tasks the TEV has two basic functions. It must be able to lift or lower a waste package and pallet and it must be able to carry the waste package with pallet from a surface facility to an emplacement drift, or vice versa.

4. NUCLEAR SAFETY DESIGN BASIS REQUIREMENTS

The following subsections will identify the NSDB requirements credited to the TEV as stated in the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Reference 9.1.1). The individual SSCs, including their functions, which are indicated in the tables contained in this section, were identified within the *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2) by close inspection of available drawings, calculations, and analysis pertaining to the TEV. The information within these subsections will form the bases for input to the matrix contained in Section 10 of this document.

4.1 NSDB REQUIREMENT 1

The mean probability of runaway of a TEV that can result in a potential breach of a waste package shall be less than or equal to 2.0×10^{-09} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

The *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2, Table 5.1-1) contains the following identified SSCs with ITS functions:

Table 4.1-1: Requirement 1 Identified SSCs and ITS Functions

SSC	ITS Function
Drive motors	To prevent overspeed from excessive electrical current
Drive Motor Integral Disc Brakes	To stop the TEV during loss of power and prevent TEV movement while stopped.
Gearboxes	To limit speed through gearing
Driveshafts	To prevent free wheeling, using splined shafts
Wheels	The limited rotational speed combined with wheel diameter limits TEV speed
Rail Brakes	To stop the TEV during loss of power and prevent TEV movement while stopped.

4.2 NSDB REQUIREMENT 2

The mean frequency of tipover of the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-06} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

The *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2, Table 5.2-1) contains the following identified SSCs with ITS functions:

Table 4.2-1: Requirement 2 Identified SSCs and ITS Functions

SSC	ITS Function
Center of Gravity / Stability	The low center of gravity of the loaded vehicle coupled with the wide rail gauge will ensure stability and prevent tipover

4.3 NSDB REQUIREMENT 3

The mean frequency of derailment of the TEV at the loadout station due to the spectrum of seismic events shall be less than or equal to 1.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

The *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2, Table 5.3-1) contains the following identified SSCs with ITS functions:

Table 4.3-1: Requirement 3 Identified SSCs and ITS Functions

SSC	ITS Function
Seismic Restraints	To prevent the TEV from derailment during a seismic event.

4.4 NSDB REQUIREMENT 4

The mean frequency of ejection of a waste package from the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

The *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2, Table 5.4-1) contains the following identified SSCs with ITS functions:

Table 4.4-1: Requirement 4 Identified SSCs and ITS Functions

SSC	ITS Function
Front Shield Door Locks	To restrain the front shield doors from WP impact while in the closed position
Front Shield Doors	To restrain the WP during WP impact while in the closed position
Front Shield Door Hinges	To restrain the front shield doors from WP impact while in the closed position

4.5 NSDB REQUIREMENT 5

The mean probability of inadvertent TEV door opening shall be less than or equal to 1.0×10^{-07} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

The *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2, Table 5.5-1) contains the following identified SSCs with ITS functions:

Table 4.5-1: Requirement 5 Identified SSCs and ITS Functions

SSC	ITS Function
Rear Shield Door Actuators	To move the rear shield door in dedicated areas only
Front Shield Door Locks	To restrain the front shield doors while in the closed position, and unlock in dedicated areas only
Circuitry (Hardwired Interlock)	Interlocking of the front shield door locks and the rear shield door to permit operation in designated areas only
Interlock Switch	To open and close its contact when actuated by external arm

5. APPLICABLE CODES AND STANDARDS

This section will provide the rationale for the selection of codes and standards considered applicable to the design, construction, and testing of the SSCs identified as performing an ITS function detailed within Section 4.

The particular code and standard, or the applicable sections will provide further input to the matrix contained in Section 6.

These codes and standards were highlighted as being applicable within the *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study* (Reference 9.1.2, Section 6). Additional codes and standards have further been identified and supplemented within this study.

5.1 ASME NOG-1-2004

Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder) (Reference 9.2.2)

The rationale for the selection of this standard to various components of the transport and emplacement vehicle is based upon the following factors:

- Dynamic seismic qualification, adopting methodologies from U.S. Nuclear Regulatory Commission regulatory guides
- Material controls, ensuring traceability of the important material properties.
- Environmental conditions, addressing requirements associated with harsh conditions, radiation, and contamination, including as low as is reasonably achievable and detrimental aging effects.
- Single failure proof includes the requirements and examples of single failure proof designs.
- Testing includes component tests, welding tests, and overall equipment tests.
- Recognition by industry. The requirements were developed and have evolved from the meetings held by the Cranes for Nuclear Facilities committee sessions attended by representatives of the U.S. Department of Energy (DOE), U.S. Nuclear Regulatory Commission, NASA, and the manufacturing industry

Further, the TEV design, construction, and testing shall be fulfilled according to the requirements for a Type I Crane. This selection is based upon the following definition of a Type I Crane:

Crane, Type I – A crane that is used to handle a critical load. It shall be designed and constructed so that it will remain in place and support the critical load during and after a seismic event, but does not have to be operational after this event. Single failure-proof features shall be included so that any *credible failure* of a single component will not result in the loss of capability to stop and hold the critical load.

Critical Load – Any lifted load whose uncontrolled movement or release could adversely affect any safety-related system when such a system is required for unit safety or could result in potential offsite exposure in excess of the limit determined by the purchaser.

5.2 DOMAN, D.R. 1988

Design Guides for Radioactive Material Handling Facilities and Equipment (Reference 9.2.3)

The rationale for the selection of this standard to the transport and emplacement vehicle front and rear shield door design is based upon the following factors:

- Environmental conditions addressing requirements associated with harsh conditions, radiation, and contamination, including as low as is reasonably achievable and detrimental aging effects.
- Redundancy designs.
- Testing includes component tests and overall equipment tests.
- Recognition by industry.

5.3 IEEE STD 336-2005

IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities (Reference 9.2.5)

The rationale for the selection of this standard is that it provides considerations for the pre-installation, installation, inspection, and testing of Class 1E power, instrumentation, and control equipment and systems of a nuclear facility while in the process of installing, inspecting, and testing during new construction, modification, and maintenance. These considerations also are appropriate for use with ITS SSCs for YMP.

The Institute for Electrical and Electronics Engineers is a recognized organization providing standards and guides for use in the nuclear power industry.

5.4 IEEE STD 384-1992 (REAF 1998)

Standard Criteria for Independence of Class 1E Equipment and Circuits (Reference 9.2.8)

The rationale for the selection of this standard is that it describes the independence requirements of the circuits and equipment for Class 1E systems. It sets forth criteria for the independence that can be achieved by physical separation and electrical isolation of circuits and equipment. While the TEV power is not ITS, the design considerations for electrical independence are appropriate for enhancing the design of the hardwired circuitry for the safety interlock for the front shield door locks and the rear shield door.

The Institute for Electrical and Electronics Engineers is a recognized organization providing standards and guides for use in the nuclear power industry.

5.5 EQUIPMENT QUALIFICATION STANDARDS

IEEE Std 323-2003, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations* (Reference 9.2.4)

IEEE Std 344-2004, *IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations* (Reference 9.2.6)

IEEE Std 383-2003, *Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations* (Reference 9.2.7)

The rationale for the selection of these standards is that they provide accepted and recognized methodologies for equipment qualification of Class 1E equipment for nuclear power plants. These methodologies also are appropriate for use with ITS SSCs for YMP. The equipment qualification efforts will be handled for YMP by a project equipment qualification program, and will not be addressed further in this gap analysis.

The Institute for Electrical and Electronics Engineers is a recognized organization providing standards and guides for use in the nuclear power industry.

6. GAP ANALYSIS MATRIX

The matrix in Section 10 provides a summary of the information given in previous sections of this report, specifically:

- The nuclear safety design basis requirements (Section 4).
- The SSCs credited with the performance of the NSDB requirements (Section 4).
- Identified codes and standards that will be used in the design, fabrication, testing, and installation of the SSCs (Section 4.4).

Where codes and standards are insufficient in assuring the SSC will perform its required safety function, a gap will be highlighted in the matrix. This gap will be filled by the following:

- Supplemental Requirements – These are supplements needed to the codes and standards identified and may include additional drawings, calculations, analyses, tests, inspections, or changes in specific requirements necessary to demonstrate that an ITS SSC will perform as required. Supplemental requirements are detailed in Section 7.
- Design Development Requirements – These are development needs identified where no code and standard exists or the NSDB requirement is one of operability or reliability. Design development requirements may include drawings, calculations, analyses or tests necessary to demonstrate that an ITS SSC will perform as required. Design development requirements are detailed in Section 8.

7. SUPPLEMENTAL REQUIREMENTS

After evaluation of the codes and standards listed in Section 4.4 that were determined as providing assurance that identified SSCs shall perform their ITS function, it may be found that the code and standards do not fully satisfy an NSDB requirement. This establishes a gap and is highlighted in the matrix in Section 10. Section 7 details the supplemental requirements, where necessary, to the codes and standards to ensure the SSCs NSDB requirements are fully satisfied and the gap is filled.

7.1 SUPPLEMENTAL REQUIREMENT 1

The NSDB Requirement Number 1 (Section 4.1) is an operational reliability requirement stating:

The mean probability of runaway of a TEV that can result in a potential breach of a waste package shall be less than or equal to 2.0×10^{-09} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

ASME NOG-1-2004 (Reference 9.2.2) adequately covers the requirements applicable to the selection of brakes, gearboxes, motors, driveshafts, and wheels. The standard will be supplemented by selection of SSCs with reliable nuclear pedigree (i.e., used in similar nuclear applications and conditions). The particular type, size, and duty are selected by conformance to the manufacturer's recommended selection procedure and calculations.

There are no additional supplemental codes and standards for NSDB Requirement Number 1.

7.2 SUPPLEMENTAL REQUIREMENT 2

The NSDB Requirement Number 2 (Section 4.2) is an operational reliability requirement stating:

The mean frequency of tipover of the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-06} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

This NSDB requirement cannot be demonstrated by the application of an industry code or standard. Current design is to maintain as wide a rail gauge as practicable within constraints of the emplacement drift operating envelope and simultaneously maintain the loaded vehicle center of gravity as low as possible to provide vehicle stability. There are no supplemental codes and standards for NSDB Requirement Number 2.

7.3 SUPPLEMENTAL REQUIREMENT 3

The NSDB Requirement Number 3 (Section 4.3) is an operational reliability requirement stating:

The mean frequency of derailment of the TEV at the loadout station due to the spectrum of seismic events shall be less than or equal to 1.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

ASME NOG-1-2004 (Reference 9.2.2) adequately covers the requirements applicable to the seismic restraints. The standard will be supplemented by selection of SSCs with reliable nuclear pedigree (i.e., used in similar nuclear applications and conditions). The particular type, size, and

duty are selected by conformance to the manufacturer's recommended selection procedure and calculations.

There are no additional supplemental codes and standards for NSDB Requirement Number 3.

7.4 SUPPLEMENTAL REQUIREMENT 4

The NSDB Requirement Number 4 (Section 4.4) is an operational reliability requirement stating:

The mean frequency of ejection of a waste package from the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

ASME NOG-1-2004 (Reference 9.2.2) and Doman, D.R. 1988 (Reference 9.2.3) adequately cover the requirements applicable to the selection of wheels. This standard and design guide will be supplemented by selection of SSCs with reliable nuclear pedigree (i.e., used in similar nuclear applications and conditions). The particular type, size, and duty are selected by conformance to the manufacturer's recommended selection procedure and calculations.

There are no additional supplemental codes and standards for NSDB Requirement Number 4.

7.5 SUPPLEMENTAL REQUIREMENT 5

The NSDB Requirement Number 5 (Section 4.5) is an operational reliability requirement stating:

The mean probability of inadvertent TEV door opening shall be less than or equal to 1.0×10^{-07} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

ASME NOG-1-2004, IEEE 336-2005, and IEEE 384-1992 (REAF 1998) (References 9.2.2, 9.2.5, and 9.2.8) adequately cover the requirements applicable to the circuit design and testing of the hardwired interlock, including the actuators and interlock switch. The standards will be supplemented by selection of SSCs with reliable nuclear pedigree (i.e., used in similar nuclear applications and conditions). Components are selected by conformance to the manufacturer's recommended selection procedure and calculations.

There are no supplemental codes and standards for NSDB Requirement number 5.

8. DEVELOPMENT REQUIREMENTS

If it is identified within Section 10 of this report that a particular NSDB requirement cannot be fully satisfied by the application of a code and standard or by supplemental activities (for example, a probability requirement), then the NSDB requirement will be the subject of design development activities. A brief summary of these activities is stated in the following subsections.

8.1 DESIGN DEVELOPMENT REQUIREMENT 1

The NSDB requirement number 1 (Section 4.1) is an operational reliability requirement stating:

The mean probability of runaway of a TEV that can result in a potential breach of a waste package shall be less than or equal to 2.0×10^{-09} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

There are identified design development activities, which includes reliability analyses, and detail design assembly drawings. For additional information on these activities, see the DDP.

8.2 DESIGN DEVELOPMENT REQUIREMENT 2

The NSDB requirement number 2 (Section 4.2) is an operational reliability requirement stating:

The mean frequency of tipover of the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-06} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

There are identified design development activities, which includes reliability analyses, tipover calculation, and detail design assembly drawings. For additional information on these activities, see the DDP.

8.3 DESIGN DEVELOPMENT REQUIREMENT 3

The NSDB requirement number 3 (Section 4.2) is an operational reliability requirement stating:

The mean frequency of derailment of the TEV at the loadout station due to the spectrum of seismic events shall be less than or equal to 1.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

There are identified design development activities, which includes reliability analyses and detail design assembly drawings. For additional information on these activities, see the DDP.

8.4 DESIGN DEVELOPMENT REQUIREMENT 4

The NSDB requirement number 4 (Section 4.4) is an operational reliability requirement stating:

The mean frequency of ejection of a waste package from the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

There are identified design development activities, which includes reliability analyses, door impact calculation, and detail design assembly drawings. For additional information on these activities, see the DDP.

8.5 DESIGN DEVELOPMENT REQUIREMENT 5

The NSDB requirement number 5 (Section 4.5) is an operational reliability requirement stating:

The mean probability of inadvertent TEV door opening shall be less than or equal to 1.0×10^{-07} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

There are identified design development activities, which includes reliability analyses, detail design assembly and wiring drawings, and P&ID and logic drawings. For additional information on these activities, see the DDP.

9. REFERENCES

9.1 DOCUMENTS CITED

9.1.1 *Basis of Design for the TAD Canister-Based Repository Design Concept*

BSC 2008. *Basis of Design for the TAD Canister-Based Repository Design Concept*. 000-3DR-MGR0-00300-000-002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: [ENG.20080229.0007](#).

9.1.2 *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study*

BSC 2008. *Waste Package Transport and Emplacement Vehicle ITS Standards Identification Study*. 800-30R-HE00-01200-000-002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: [ENG.20080306.0003](#).

9.1.3 *Quality Management Directive*

BSC 2007. *Quality Management Directive*. QA-DIR-10, Rev. 1. Las Vegas, Nevada: Bechtel SAIC Company. ACC: [DOC.20070330.0001](#).

9.1.4 *Engineering Studies*

EG-PRO-3DP-G04B-00016, Rev. 4. *Engineering Studies*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: [ENG.20070406.0004](#).

9.2 CODES AND STANDARDS

9.2.1 *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems*

ANSI/IEEE Std 352-1987. *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems*. New York, New York: The Institute of Electrical and Electronics Engineers. TIC: [246332](#).

9.2.2 *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)*

ASME NOG-1-2004. 2005. *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)*. New York, New York: American Society of Mechanical Engineers. TIC: [257672](#).

9.2.3 *Design Guides for Radioactive Material Handling Facilities and Equipment* Doman, D.R. 1988. *Design Guides for Radioactive Material Handling Facilities and Equipment*. La Grange Park, Illinois: American Nuclear Society. TIC: [9358](#).

9.2.4 *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*

IEEE Std 323-2003. 2004. *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*. New York, New York: Institute of Electrical and Electronics Engineers. TIC: [255697](#).

9.2.5 *IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities*

IEEE Std 336-2005. 2006. *IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities*. New York, New York: Institute of Electrical and Electronics Engineers. TIC: [258593](#).

9.2.6 *IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*

IEEE Std 344-2004. 2005. *IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*. New York, New York: Institute of Electrical and Electronics Engineers. TIC: [258050](#).

9.2.7 *Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations*

IEEE Std 383-2003. 2004. *Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations*. New York, New York: Institute of Electrical and Electronics Engineers. TIC: [256201](#).

9.2.8 *Standard Criteria for Independence of Class 1E Equipment and Circuits*

IEEE Std 384-1992 (REAF 1998). 1998. *Standard Criteria for Independence of Class 1E Equipment and Circuits*. New York, New York: Institute of Electrical and Electronics Engineers. TIC: [258693](#).

10. APPENDIX – GAP ANALYSIS MATRIX

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10.1 NUCLEAR SAFETY DESIGN BASES REQUIREMENT 1

The mean probability of runaway of a TEV that can result in a potential breach of a waste package shall be less than or equal to 2.0×10^{-09} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

Table 10.1-1. NSDB Requirement 1

Applicable SSCs	ITS Code and Standard Applicability						ITS Supplemental Requirements						ITS Design Development Requirements				Remarks or Comments
	Code or Standard (Section 4.1)	Applicable Section or Paragraph	Required Calculation	Required Drawings	Required Modeling	Required Testing	Additional Criteria	Applicable Section	Required Calculation	Required Drawings	Required Modeling	Required Testing	Required Analysis	Required Drawings	Required Modeling	Required Testing	
All SSCs Below	Identified below	N/A	N/A	N/A	N/A	N/A	Identified below	N/A	N/A	N/A	N/A	N/A	Reliability Analyses	Detail Design Assembly Drawings	N/A	N/A	See Section 8.1 (References 9.2.1 or equivalent reliability analyses)
Drive System (Motor, Gearboxes, Driveshafts, Wheels, Brakes)	ASME NOG-1-2004 (Reference 9.2.2)	5000 5141 5150-(a) 5440 5443 5452 5453 5457 6000 6420 6423 6470 7000 7220 7253 B5476	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	Selection of components with a reliable nuclear pedigree and according to suppliers selection procedures.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Section 7.1

10.2 NUCLEAR SAFETY DESIGN BASES REQUIREMENT 2

The mean frequency of tipover of the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-06} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

Table 10.2-1. NSDB Requirement 2

Applicable SSCs	ITS Code and Standard Applicability						ITS Supplemental Requirements						ITS Design Development Requirements				Remarks or Comments
	Code or Standard (Section 4.2)	Applicable Section or Paragraph	Required Calculation	Required Drawings	Required Modeling	Required Testing	Additional Criteria	Applicable Section	Required Calculation	Required Drawings	Required Modeling	Required Testing	Required Analysis	Required Drawings	Required Modeling	Required Testing	
Center of Gravity / Stability	ASME NOG-1-2004 (Reference 9.2.2)	4000 4457	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	None	N/A	N/A	N/A	N/A	N/A	Reliability Analyses Tipover calculation	Detail Design Assembly Drawings	N/A	N/A	See Section 8.2 (References 9.2.1 or equivalent reliability analyses)

10.3 NUCLEAR SAFETY DESIGN BASES REQUIREMENT 3

The mean frequency of derailment of the TEV at the loadout station due to the spectrum of seismic events shall be less than or equal to 1.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

Table 10.3-1. NSDB Requirement 3

Applicable SSCs	ITS Code and Standard Applicability						ITS Supplemental Requirements						ITS Design Development Requirements				Remarks or Comments
	Code or Standard (Section 4.3)	Applicable Section or Paragraph	Required Calculation	Required Drawings	Required Modeling	Required Testing	Additional Criteria	Applicable Section	Required Calculation	Required Drawings	Required Modeling	Required Testing	Required Analysis	Required Drawings	Required Modeling	Required Testing	
Seismic Restraints	ASME NOG-1-2004 (Reference 9.2.2)	4000 4457	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	None	N/A	N/A	N/A	N/A	N/A	Reliability Analyses	Detail Design Assembly Drawings	N/A	N/A	See Section 8.3 (References 9.2.1 or equivalent reliability analyses)

10.4 NUCLEAR SAFETY DESIGN BASES REQUIREMENT 4

The mean frequency of ejection of a waste package from the TEV due to the spectrum of seismic events shall be less than or equal to 2.0×10^{-04} /yr. (Reference 9.1.1, Section 14.2.3.1.1).

Table 10.4-1. NSDB Requirement 4

Applicable SSCs	ITS Code and Standard Applicability						ITS Supplemental Requirements						ITS Design Development Requirements				Remarks or Comments
	Code or Standard (Section 4.4)	Applicable Section or Paragraph	Required Calculation	Required Drawings	Required Modeling	Required Testing	Additional Criteria	Applicable Section	Required Calculation	Required Drawings	Required Modeling	Required Testing	Required Analysis	Required Drawings	Required Modeling	Required Testing	
All SSCs Below	Identified below	N/A	N/A	N/A	N/A	N/A	None	N/A	N/A	N/A	N/A	N/A	Reliability Analyses Door Impact calculation	Detail Design Assembly Drawings	N/A	N/A	See Section 8.4 (References 9.2.1 or equivalent reliability analyses)
Front Shield Door Locks	ASME NOG-1-2004 (Reference 9.2.2)	4000 6000 7000 7220 7253	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Doman, D.R. 1988 (Reference 9.2.3)	Guide Number 4															
Front Shield Doors	ASME NOG-1-2004 (Reference 9.2.2)	4000	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Doman, D.R. 1988 (Reference 9.2.3)	Guide Number 4															
Front Shield Door Hinges	ASME NOG-1-2004 (Reference 9.2.2)	4000	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	None	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Doman, D.R. 1988 (Reference 9.2.3)	Guide Number 4															

10.5 NUCLEAR SAFETY DESIGN BASES REQUIREMENT 5

The mean probability of inadvertent TEV door opening shall be less than or equal to 1.0×10^{-07} per transport. (Reference 9.1.1, Section 14.2.3.1.1).

Table 10.5-1. NSDB Requirement 5

Applicable SSCs	ITS Code and Standard Applicability						ITS Supplemental Requirements						ITS Design Development Requirements				Remarks or Comments
	Code or Standard (Section 4.5)	Applicable Section or Paragraph	Required Calculation	Required Drawings	Required Modeling	Required Testing	Additional Criteria	Applicable Section	Required Calculation	Required Drawings	Required Modeling	Required Testing	Required Analysis	Required Drawings	Required Modeling	Required Testing	
All SSCs Below	Identified below	N/A	N/A	N/A	N/A	N/A	Identified below	N/A	N/A	N/A	N/A	N/A	Reliability Analyses	Detail Design Assembly and Wiring Drawings, P&IDs and Logic Drawings	N/A	N/A	See Section 8.5 (References 9.2.1 or equivalent reliability analyses)
Rear Shield Door Actuators	ASME NOG-1-2004 (Reference 9.2.2)	6000 6470 7000 7220 7253	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	Selection of components with a reliable nuclear pedigree and according to suppliers selection procedures.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Section 7.5
	Doman, D.R. 1988 (Reference 9.2.3)	Guide Number 4															
Front Shield Door Locks	ASME NOG-1-2004 (Reference 9.2.2)	4000 6000 7000 7220 7253	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	Selection of components with a reliable nuclear pedigree and according to suppliers selection procedures.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Section 7.5
	Doman, D.R. 1988 (Reference 9.2.3)	Guide Number 4															
Circuitry for Hardwired Interlock	ASME NOG-1-2004 (Reference 9.2.2)	6000 6440 7000 7220 7253	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	Selection of components with a reliable nuclear pedigree and according to suppliers selection procedures.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Section 7.5
	IEEE 336-2005 (Reference 9.2.5)	Entire															
	IEEE 384-1992 (REAF 1998) (Reference 9.2.8)	Entire															
Interlock Switch	ASME NOG-1-2004 (Reference 9.2.2)	6000 6440 7000 7220 7253	Selection in accordance with stated code and standard guidelines	N/A	N/A	Testing and inspection in accordance with stated code and standard guidelines	Selection of components with a reliable nuclear pedigree and according to suppliers selection procedures.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Section 7.5
	IEEE 336-2005 (Reference 9.2.5)	Entire															
	IEEE 384-1992 (REAF 1998) (Reference 9.2.8)	Entire															